

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
27 November 2003 (27.11.2003)

PCT

(10) International Publication Number
WO 03/098301 A2

(51) International Patent Classification⁷: **G02B 6/36, 6/38**

(21) International Application Number: **PCT/GB03/01994**

(22) International Filing Date: **7 May 2003 (07.05.2003)**

(25) Filing Language: **English**

(26) Publication Language: **English**

(30) Priority Data:
0211467.6 18 May 2002 (18.05.2002) GB

(71) Applicant (*for all designated States except US*): **QINETIQ LIMITED [GB/GB]; 85 Buckingham Gate, London SW1E 6PD (GB).**

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **BURNETT, James, Gordon [GB/GB]; QinetiQ Malvern, Malvern Technology Park, St Andrews Road, Malvern, Worcestershire WR14 3PS (GB). LLOYD, Peter, Arthur [GB/GB]; DSTL Farnborough, Ively Road, Farnborough, Hampshire GU14 0LX (GB).**

(74) Agent: **DAVIES, Philip; IP Qinetiq Formalities, Cody Technology Park, A4 Building, Room G016, Ively Road, Farnborough, Hampshire GU14 0LX (GB).**

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:

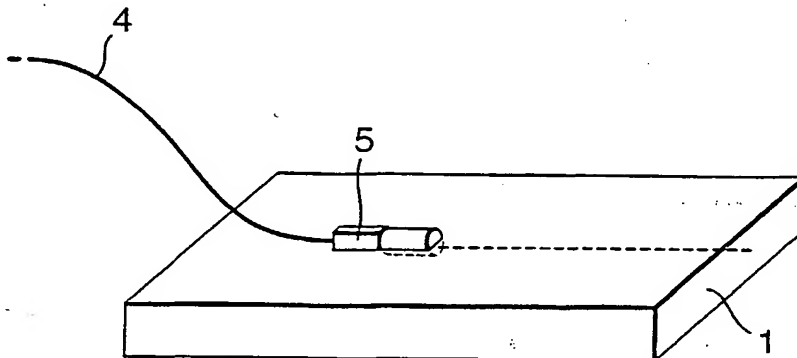
— *of inventorship (Rule 4.17(iv)) for US only*

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **FIBRE OPTIC CONNECTOR**



(57) Abstract: A method and apparatus for connecting an optical fibre mounted internally inside a composite structure to an external optical fibre. The method uses a 0.5 pitch GRIN lens mounted partly inside the structure with its optical axis offset from that of the internal fibre. The opposite end of the GRIN lens connects optically to the external fibre, also offset by the same amount but opposite side. Light is transmitted between the two fibres via the GRIN lens. Alternatively, the single 0.5 pitch GRIN lens may be two 0.25 pitch GRIN lenses separated by a glass channel. This allows the internal fibre to be mounted deeper inside the structure.

WO 03/098301 A2

- 1 -

Fibre Optic Connector.

The invention concerns a method of connecting an optical fibre embedded in a
5 structure to an external optical fibre and to a connector for connecting two such fibres.

Optical fibres are embedded into composite structures for several reasons. For
example as sensors to measure strain or temperature within a structure such as
aircraft wings. It is advantageous to be able to provide connections to these
10 embedded fibres via externally located optical fibres to monitoring equipment,
detectors and the like. Signals travelling within the optical fibres are light signals and
the term light includes both visible light and other frequencies such as infra red
frequencies.

15 One problem with connecting internal and externally located optical fibres is that of
accurate alignment. Several solutions have been proposed including those described
in US patent 5,355,429, US patent 6,035,084, US patent 6,035,084, EP 0933659-A1,
and a book Fibre Optic Smart Structures, edited by Eric Udd, published by John Wiley
& Sons Inc., ISBN 0-471-55448-0, 1995, chapter 6 methods of fibre optic
20 ingress/egress for smart structures, pages 121-153. Often the internal fibre exits the
structure at an edge that allows use of edge connectors fixed to the edge of the
structure. For other structures it is necessary for the internal fibre to terminate from
the structure at its surface away from an edge. Solutions to this include extending the
fibre outside the structure when a layered structure is made, e.g. USP 5,355,429.

25 According to this invention, the problem of aligning an internal and an external optical
fibre is solved by use of a graded index (GRIN) lens between the two fibres.

- 2 -

According to this invention a method of connecting an optical fibre within a structure to an external optical fibre comprises the steps of mounting an internal fibre within a structure,

- 5 providing a 0.5 pitch GRIN lens having an optical axis and a first and a second face through which the optical axis passes,
optically connecting the first end of the GRIN lens to the internal fibre with the optical axis of the GRIN lens offset from the internal optical fibre,
mounting an external fibre in optical contact with the second end of the GRIN lens
- 10 with the external fibre mounted offset from the optical axis of the GRIN lens,
the arrangement being such that light can travel between the internal fibre and external fibre through the GRIN lens.

- 15 The external fibre may be cemented to the GRIN lens and held in position by a potting compound, or held in a connector separably connected to the structure.

- According to this invention a connector for carrying out the method of this invention comprises a structure carrying an internal optical fibre embedded within its bulk, a 0.5 pitch GRIN lens having input and output faces at either end of an optical axis,
- 20 the GRIN lens being mounted partly within the structure in optical contact with the internal fibre and with the optical axis offset from the internal fibre,
and an external optical fibre mounted in optical contact with the GRIN lens and offset from the optical axis,
the arrangement being such that light can travel between the internal and external
 - 25 fibres.

- 3 -

The GRIN lens may be a single 0.5 pitch lens or two 0.25 pitch lenses separated by an optical channel such as a glass rod. This allows the internal fibre to be located much deeper inside the structure. Both 0.5 and 0.25 pitch GRIN lenses are commercially available, e.g. from Nippon Sheet Glass Company. The term pitch
5 relates to the number of cycles that are associated with the sinusoidal trajectory of an optical ray propagating from the input face of the GRIN lens to its output face. The sinusoidal trajectory of an optical ray propagating along a GRIN lens is a consequence of the quadratic refractive index profile of the GRIN lens. An optical ray that propagates along a ray path trajectory equal to one cycle of a sinusoid has a
10 pitch of 1.0. The terms 0.5 and 0.25 pitch GRIN lens is to be taken as including 0.5, 0.25 and functional or nominal or substantial equivalents, because pitch length is frequency dependent.

A 0.25 pitch lens will propagate rays through a quarter of a sinusoid cycle and
15 therefore all rays emanating from a point on the input face of a 0.25 GRIN lens (provided these rays propagate within the numerical aperture of the GRIN lens) will exit the GRIN lens at its output face co-linearly (i.e. they will describe a collimated beam). A 0.5 pitch lens will propagate rays through a half of a sinusoid cycle and therefore all rays emanating from a point on the input face of a 0.5 pitch GRIN lens
20 (provided these rays propagate within the numerical aperture of the GRIN lens) will converge to a conjugate point on the output face of the GRIN lens.

The GRIN lens or lenses may be polished to adjust their optical length to compensate for increased optical path length caused by the offset connections. Alternatively, the
25 GRIN lenses may be selected from a different wavelength specification that will match with the required wavelength's increased path length.

The optical fibres may be single core or multi core fibres, and may be arranged with their optical axis parallel or non-parallel to the optical axis of the adjacent GRIN lens.

- 4 -

The invention will now be described, by way of example only, with reference to the accompanying drawings of which:

- 5 Figure 1 is a perspective view of a structure containing an optical fibre and connecting to an external optical fibre; and

Figure 2 is a cross section of Figure 1,

- 10 Figure 3 is an enlarged view of the lens in Figures 1, 2, and,

Figure 4 is a cross section of another form of the invention, useful when an optical fibre is located deep below the surface of a structure.

- 15 As shown a structure 1 comprises several layers of material such as carbon fibre cloth in a resin matrix formed into a component which may be a part of an aircraft wing. Embedded within the structure is an internal optical fibre 2 placed in position during manufacture of the structure. The fibre is a conventional fibre with a light transmitting core and an outer cladding. Use of structures with embedded optical
- 20 fibres is a known art; often the structures are termed smart structures because their physical condition and health can be monitored during use. The embedded fibre can detect changes to and within the structure.

- A graded index (GRIN) lens 3 is partly embedded in the structure with one end in
- 25 optical contact with the end of the internal fibre. Outside of the structure 1 is an external optical fibre 4 held in a potting compound 5 in optical contact with the GRIN lens 3. Preferably, the external fibre 4 is held within a separable connector as shown in Figure 4. A capillary tube (not shown) may be used to support the fibre 4 at it junction with the GRIN lens 3.

30

- 5 -

The lens 3 has a 0.5 pitch measured along an optical axis 6 between end faces 7,8. This lens 3 has the property of taking a point light source input on one end, expanding the light from the source and focussing it back down to a point at the opposite end of the lens. The internal fibre 2 has its core arranged at an offset of $-x$ from the optical axis 6 of the lens 3. Similarly the external fibre has its core offset by $+x$. This ensures that the (almost) point light from the internal fibre 2 is directed into the core of the external fibre 4 with minimal loss. Due to the two offsets, the optical path within the lens 3 is increased. Therefore it is preferable to polish one end face of the lens 3 to bring the optical path back to 0.5 pitch.

10

The embodiment of Figures 1-3 is useful when the internal fibre is located close to the component surface. Figure 4 shows how a deeper mounted internal fibre 2 can be connected to an external optical fibre 4. Two 0.25 (nominal) pitch GRIN lenses 11 and 12 are connected by a length of glass channel 13 and to the internal and external fibres 2, 4 respectively. The external fibre 4 may be cemented to the GRIN lens 12 or mounted in a separable connector 14, 15. In the example shown two SELFOC SLS-2.0 GRIN lenses (obtainable from NSG) were used. The lenses 11, 12 however were modified in that their lengths were reduced from a nominal length of 6.631mm to 6.595mm through optically polishing one face of the lens. This was necessary since due to the relatively large lateral offset of the fibres 2, 4 from the optic axis of the lenses, the effective pitch of the lenses was slightly greater than 0.25.

20

In one example, the propagation path in the glass channel 13 was 20mm, and the internal fibre 2 was embedded at a depth of 2.965mm in a structure 1 thickness of approximately 6mm.

25

- 6 -

Claims.

1. A method of connecting an optical fibre within a structure to an external optical fibre comprising the steps of mounting an internal fibre within a structure,
5 providing a 0.5 pitch GRIN lens having an optical axis and a first and a second face through which the optical axis passes,
optically connecting the first end of the GRIN lens to the internal fibre with the optical axis of the GRIN lens offset from the internal optical fibre,
mounting an external fibre in optical contact with the second end of the GRIN lens
10 with the external fibre mounted offset from the optical axis of the GRIN lens,
the arrangement being such that light can travel between the internal fibre and external fibre through the GRIN lens.
2. The method of claim 1 wherein the GRIN lens is a single 0.5 nominal pitch lens.
15
3. The method of claim 1 wherein the GRIN lens is formed by two 0.25 nominal pitch lenses 11, 12 separated by an optical channel 13.
4. The method of claim 1 wherein the external fibre is held in a connector separably
20 connected to the structure.
5. A connector for carrying out the method of this invention comprising:
a structure carrying an internal optical fibre embedded within its bulk,
a 0.5 pitch GRIN lens having input and output faces at either end of an optical axis,
25 the GRIN lens being mounted partly within the structure in optical contact with the internal fibre and with the optical axis offset from the internal fibre,
and an external optical fibre mounted in optical contact with the GRIN lens and offset from the optical axis,
the arrangement being such that light can travel between the internal and external
30 fibres.

- 7 -

6. The connector of claim 5 wherein the GRIN lens (3) is a single 0.5 nominal pitch lens.
7. The connector of claim 5 wherein the GRIN lens (3) is formed by two 0.25 nominal pitch lenses 11, 12 separated by an optical channel 13.
8. The connector of claim 5 wherein the external optical fibre 4 is connected to the GRIN lens (3, or 12) by a separable connector (14, 15).
9. The connector of claim 5 wherein the external optical fibre 4 is connected to the GRIN lens (3, or 12) by an optical cement (5).
10. The connector of claim 5 wherein the optical fibres are multi core fibres.
11. The connector of claim 5 wherein the optical fibres are single core fibres.

1/2

Fig.1.

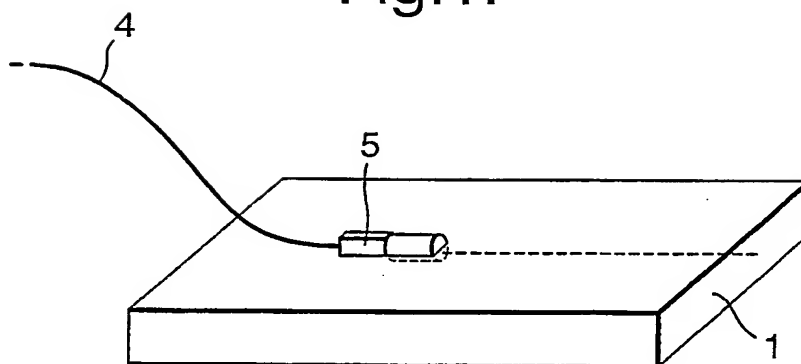
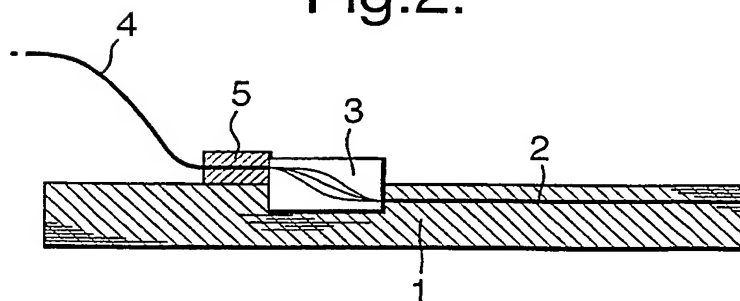


Fig.2.



2/2

Fig.3.

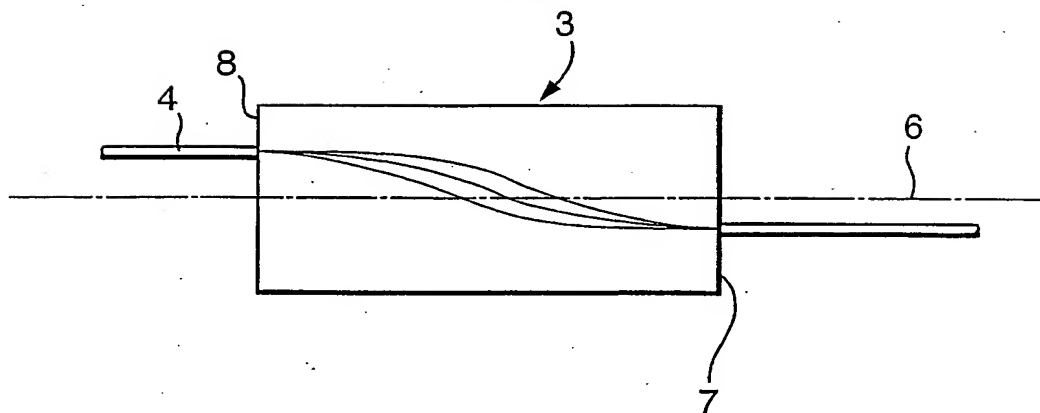
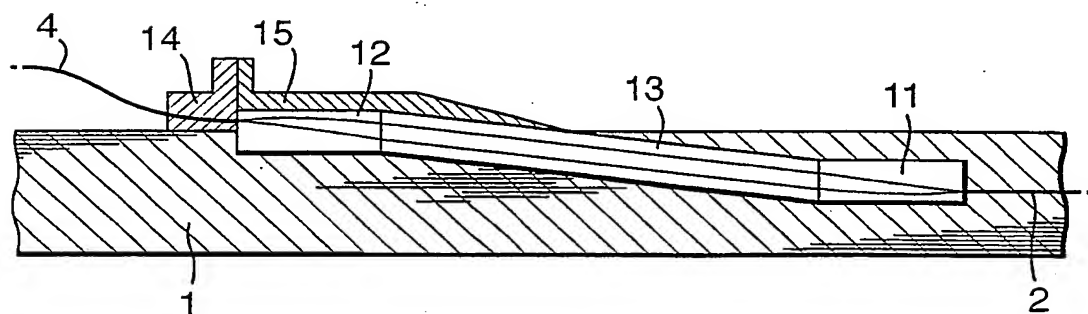


Fig.4.



(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
27 November 2003 (27.11.2003)

PCT

(10) International Publication Number
WO 2003/098301 A3

(51) International Patent Classification⁷: **G02B 6/36,**
6/38, 6/32

(21) International Application Number:
PCT/GB2003/001994

(22) International Filing Date: 7 May 2003 (07.05.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0211467.6 18 May 2002 (18.05.2002) GB

(71) Applicant (for all designated States except US): **QINETIQ LIMITED** [GB/GB]; 85 Buckingham Gate, London SW1E 6PD (GB).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **BURNETT, James,**
Gordon [GB/GB]; QinetiQ Malvern, Malvern Technology

Park, St Andrews Road, Malvern, Worcestershire WR14 3PS (GB). **LLOYD, Peter, Arthur** [GB/GB]; DSTL Farnborough, Ively Road, Farnborough, Hampshire GU14 0LX (GB).

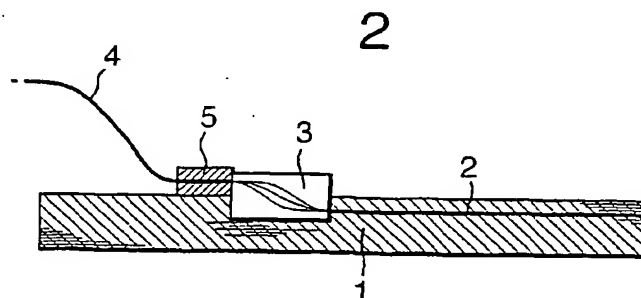
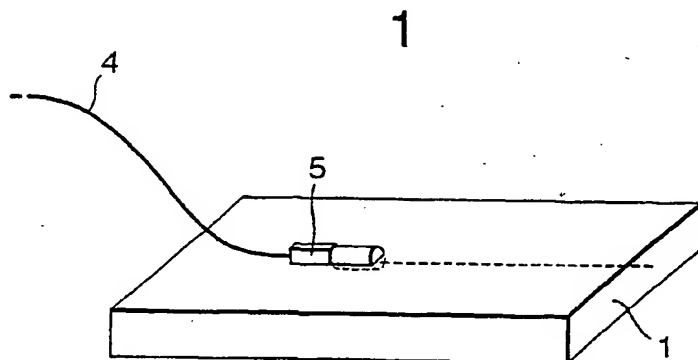
(74) Agent: **DAVIES, Philip**; IP Qinetiq Formalities, Cody Technology Park, A4 Building, Room G016, Ively Road, Farnborough, Hampshire GU14 0LX (GB).

(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),

[Continued on next page]

(54) Title: FIBRE OPTIC CONNECTOR



(57) Abstract: A method and apparatus for connecting an optical fibre mounted internally inside a composite structure to an external optical fibre. The method uses a 0.5 pitch GRIN lens mounted partly inside the structure with its optical axis offset from that of the internal fibre. The opposite end of the GRIN lens connects optically to the external fibre, also offset by the same amount but opposite side. Light is transmitted between the two fibres via the GRIN lens. Alternatively, the single 0.5 pitch GRIN lens may be two 0.25 pitch GRIN lenses separated by a glass channel. This allows the internal fibre to be mounted deeper inside the structure.

WO 2003/098301 A3



Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE,
ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO,
SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM,
GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

— before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments

Declaration under Rule 4.17:

— of inventorship (Rule 4.17(iv)) for US only

Published:

— with international search report

(88) Date of publication of the international search report:
4 March 2004

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

Internat Application No

PCT, 03/01994

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G02B6/36 G02B6/38 G02B6/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 39 32 655 A (SIEMENS AG) 11 April 1991 (1991-04-11) abstract; claims 1-8; figures 1,2	1,5
A	WO 01 81961 A (STANDARD MEMS INC ;FRICANO GLENN J (US); TRIMMER WILLIAM (US)) 1 November 2001 (2001-11-01) abstract; figures 1-3	1,5
A	US 5 355 429 A (LEE NICHOLAS A ET AL) 11 October 1994 (1994-10-11) cited in the application abstract; figures 1-12	1,5
A	US 6 035 084 A (DUNNE JAMES P ET AL) 7 March 2000 (2000-03-07) cited in the application abstract; figures 1-5	1,5
-/-		



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- * & * document member of the same patent family

Date of the actual completion of the international search

15 December 2003

Date of mailing of the international search report

22/12/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Malic, K

INTERNATIONAL SEARCH REPORT

Internat Application No
PCT, GB 93/01994

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>EP 0 933 659 A (JDS FITEI INC) 4 August 1999 (1999-08-04) cited in the application abstract; figures 1-9</p>	1,5

INTERNATIONAL SEARCH REPORT

tion on patent family members

Intern: Application No

PCT, GB 03/01994

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
DE 3932655	A	11-04-1991	DE 3932655 A1	11-04-1991
WO 0181961	A	01-11-2001	AU 7784301 A	07-11-2001
			WO 0181961 A2	01-11-2001
			US 2002057871 A1	16-05-2002
US 5355429	A	11-10-1994	FR 2700021 A1	01-07-1994
			GB 2274178 A , B	13-07-1994
US 6035084	A	07-03-2000	NONE	
EP 0933659	A	04-08-1999	US 6014484 A	11-01-2000
			AU 736252 B2	26-07-2001
			AU 9813898 A	19-08-1999
			CA 2256886 A1	29-07-1999
			EP 0933659 A1	04-08-1999
			US 6393179 B1	21-05-2002